ATTRACTIVENESS OF BUS SYSTEM STUDIED WITH INFORMATION INTEGRATION THEORY

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By
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DEDICATED

TO

MY PARENTS

CERTIFICATE

This is to certify that the study entitled 'Attractiveness of Bus System Studied with Information Integration Thery' has been carried out by Mr. Y.N. Pradhan under our supervision and has not been submitted elsewhere for the award of a degree.

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SYNOPSIS

In two experiments, actual bus users were given descriptions of hypothetical bus systems, and were asked to indicate how much they would like to travel in the so-designed buses. Buses were constructed according to a 3 x 3 x 3 , Fare x Frequency x Comfort factorial design, and all the hypothetical buses were presented to each subject.

Information integration theory, which deals with the measurement of subjective values and with the determination of coordination rule, was applied to study the attractiveness of bus systems. According to the theory, attractiveness of bus systems should obey a multiplying model. That is, plot of the profile of two-way interaction from the three-way, Fare x Frequency x Comfort design should show a linear fan shape. In Experiment 1, this prediction was partially supported. While Fare x Comfort and Frequency x Comfort effects had the predicted linear fan shape, Fare x Frequency and Fare x Frequency x Comfort effects showed parallelism. A compound adding-multiplying model was thus able to account for the attractiveness judgement.

Experiment 2 was run as a reliability check on the results of Experiment 1. Results of this experiment disclosed that attractiveness of bus indeed follows a multiplying model.

This difference in results between two experiments appear to be attributable to the difference in sensitivity of the two experiments.

In both experiments, it was found that the psychological values of the bus characteristics did not match with their objective values. For example, the difference between 50 Paise and Re. 1 was much larger than the difference between Re. 1 and Rs. 1.50. A similar trend was noticable in the perception of the scale of time. These results suggest that the traditional approaches to modal choice are faulty . In general,regression analysis has been used in transportation research. Regression analysis assumes that objective values of the modal characteristic are known and fixed. This notion can no longer be acceptable because the present results show that there is no close correspondence between the physical and subjective values of stimuli.

For a better prediction of modal choice,we must consider how the different attributes are valued and weighted by the users. It was suggested that information integration theory is ideally suited for such purpose.

CHAPTER 1

Introduction

General

Knowledge of how people perceive alternative designs and operating strategies of existing or proposed transportation systems can be important for its successful planning, implementation and operation. In order to plan successful bus operations, it is necessary to understand the factors that influence travelers' choice among alternative bus systems. A knowledge of the sensitivity of users' preferences to varying levels of service characteristics enables planners to develop alternative transport systems.

To determine the user response to a bus system and to make policy decisions, planners must know (1) which attributes in a proposed system are relevent to the user, and (2) how these different attributes operate in the determination of an overall preference. This study is an attempt to analyze people's attitudes toward various bus systems.

The attitudes of individuals towards transportation systems, their component and characteristics can be measured, using various techniques developed in consumer psychology and applied market research. Attitude measurement can thus be used either as statistical technique to summarize opinions

and point of view or as explanatory variable and parameter in models of individuals overall perference. Choice models involving attitudinal variables are the most general class of models.

The purpose of the present study was to model individual's preferences to a set of hypothetical bus transportation systems, using Norman H. Anderson's theory of information integration (Anderson, 1974a, 1979). Information integration theory is a unified, general theory of human judgement. It deals with the problems of multiple causation, that is, how do different causal forces operate in producing a unitary perception or judgement. It can thus be expected to be useful in modelling decision process of bus users.

Survey of Literature

The estimation of travel demand has been a subject of interest in most urban transportation studies. Accurate estimation and prediction of travel demand have thus become increasingly important as aids to the decision making in the complex issues on investment priorities among transportation alternatives. This problem exists both in the context of urban areas as well as regional corridors. Most of the models in this area have been developed largely

for predicting travel within urban area, and so they cannot meet the accuracy requirements of the decision makers and policy-makers. There have been numerous attempts during the past few years to develop new strategies and techniques for modelling travel-demand rectifying the inconsistencies embedded in the earlier approaches.

Within the problem area of travel demand estimation, the specific problem of travel-mode choice is of considerable interest. This is more so in the context of problems associated with modelling modal choice in our country due to the diverse nature of market for various modes. In the past, almost every transportation study has developed its own modal-split model, where as models of the remaining elements of travel demand-trip generation, trip distribution, and assignment are much more standarized especially in the context of conditions prevailing in the United States. Studies conducted in connection with improving transportation situation in our country virtually pay a lip service to this improvement element of the travel demand analysis. Projections have been made on ad hoc basis regarding the future share of various evolving modes in urban as well as interurban areas.

Modal-split modelling derives an amount of added interest from the fact that it has considerable potentials in aiding investment decisions among transport modes. It can

potentially indicate the likely outcomes of various decisions , a problem which has been currently drawing the attention of the National Transport Policy Committee of the Government of India in 1978. Although numerous modal-choice models have been developed elsewhere, these models can largely be classified into a small number of categories wherein the properties of the individual models are susceptible to general description.

The first major transportation studies were carried out in the mid-1950s. Various attempts were made to build models of the modal choice process. These studies can be briefly classified into three principal categories.

The earliest of these models attempted to predict modal choice at an aggregate level by using characteristics of the aggregated areas, such as zones and districts. These characteristics consituted socioeconomic measures of the population of the aggregated areas and measures of attraction of these areas in terms of activity levels of various land uses. Because the models did not contain any characteristics of the modes, these models failed to account for the changes in these characteristics. Because the socioeconomic measures incorporated are generally increasing (e.g.; income, and level of education),predictions about the choice of these modes in future cannot be made.

The second generation of models came into existence in the early 1960s. Even though they operated at an aggregate level described above, they incorporated some characteristics of the transportation system such as time, cost, frequency, etc. The diversion curve model developed by the Traffic Research Corporation is an example of this type of model. However, these second-generation models are also aggregate models. They thus have the same drawbacks in the sense that they can neither be transferred geographically, nor can they be readily subdivided. These models are deterministic, for they yield modal volumes rather than probabilities of using a particular mode. Deterministic models of such type have wide confidence limits statistically. Accordingly, they are of limited use in explanation as well as prediction. These models have been developed after the trip distribution phase with the following form:

$$\frac{T^1_{ij}}{T^2_{ij}} = f\ (\ C^1_{ij}\ ,\ C^2_{ij}\ ,\ SE_i,\ LU_j\ ), \qquad (1)$$

where T^1_{ij} = Number of trips generated by zone i, attracted by zone j, which moves via mode 1.

T^2_{ij} = Number of trips generated by zone i, attracted by zone j, which moves via mode 2.

C^1_{ij} = Travel impedence between i and j via mode 1.

C_{ij}^2 = Travel impedence between i and j via mode 2.

SE_i = Socioeconomic characteristics of population of originating zone i.

LU_j = Land use characteristics of destination zone j.

f = Functional form.

That is, the number of trips distributed between zonal pairs is allocated between the two modes under consideration on the basis of travel times, cost, and other tangible factors between modes, and also in some cases on the basis of selected socioeconomic characteristics of the origin zone and land use characteristics of the destination zone. The diversity of modes is usually ignored or handled by combining all modes into dichotomous modes. This is the only model which is fundamentally behavioural and policy-oriented.

Although the policy-oriented model mentioned above is a step in the right direction, it is difficult to provide adequate test of it. By its structure, the model is a regression model which assumes that the values of the predictors are known. As values of predictors cannot be known for sure, it is perhaps advantageous to have an approach which measures values of each predictor at the level of each modal user. In order to overcome some of the problems mentioned above, there have been attempts in the past to build new models of travel-mode choice based on the application of theories of

individual behaviour in decission making choices. Initially disaggregate behavioural models were conceived of as operating within the same model structure as the conventional urban transport planning package of models.

The main advantage of this approach is that modal choice is analogous to the typical market place decision situation. The individual buyer, namely, the traveler has to choose between a number of goods or services according to their attributes and his set of preferences. This approach represents a major change in emphasis in a sense that these models are disaggregate, and they attempt to model individual behaviour on the basis of mode and user attributes. They have been developed to predict individual behaviour by assigning to individuals probabilities of using modes in a binary choice situation. It appears that these models can better reproduce existing conditions, regardless of geographic location, and give more reasonable responses to forecasts of mode and user characteristics than models of type described in the earlier section. This procedure is most consistent with modern theories of human discrimination and choice which state that every human decision is in essence probabilistic.

Placed in the context of modal choice, this approach effectively states that an individual will choose a mode with

probability determined by trip considerations and his own scaling of the effectiveness of the alternatives for that trip purpose.

Thus, the stochastic model of modal choice may be considered as a translation of the theoretical elements of decision-making into operational terms. Based on the revealed preferences by travelers in their modal choices, the models distinguish between the attraction and disutility of the system characteristics and user characteristics that affect the preference scale of system attributes. More specifically, the models can incorporate a variety of system characteristics, provided that adequate quantification can be achieved, and may include attributes derived from attitudinal studies. These models have several properties that are of help in analyzing modal choice.

First, these models have greater predictive validity than conventional models, because they are based on the behaviour patterns of individuals rather than on statistically derived correlations in aggregate analysis.

A second property of these models is that they are based on the smallest element of the population- - the individual. As such, the large variances attributed to problems of zoning or of aggregation of population attributes are eliminated. Thus, the predictions from the models must have much narrower confidence limits than those of aggregate

models.

A third property, also stemming from the disaggregate approach, relates to the eventual aggregation that must be used for the models to be applied to large urban areas. Because the models are constructed from the smallest population elements, the level of aggregation can be determined from the models as the precision of measurement required to yield the desired predictive accuracy. In contrast to earlier modal choice models, a stochastic disaggregate model is a deductive model which determines a priori the variables to be measured and the level of aggregation and the groupings for aggregation that are required for operation of the model.

A fourth property of stochastic disaggregate models is that they provide a basis for inferring the relative importance that people place on various characteristics of the transportation systems. These values may be derived from an examination of the relative weights of each system characteristic on the choice process described by the model. The behavioural basis of the models requires that the values so obtained be behaviourally consistent.

However, a single model is still used to describe the behaviour of all individuals in a given sample. Nevertheless, this approach does make explicit the need to indentify homogeneous groups of decision-makers.

Various factors were included in the mode choice models such as trip purpose, income of individual, demographic aspect of the region, operating characteristics of transit and auto systems, and attitude toward the quality of alternative modes. But they used actual values of some of the attributes such as time, cost, etc. rather than the perceived values.

Relative measures and nonlinear response transformations were also used to determine the probabilities and assumed a linear integration process. The coefficient of each variable was taken as a weight and was assumed constant for all levels of that variable. Two problems are associated with these assumptions in applying to long-term forecasting: (a) absence of goodness-of-fit tests and (b) insensitivity of correlation approach (Shanteau and Anderson, 1977).

Therefore, there is a need to develop a model that reflect causal relationships. The model must be behavioural, flexible and must allow policy makers to describe the existing relationship among variables and predict the effect of changes in these variables. Information integration approach has been used successfully in these types of research(e.g., Singh, 1975; Singh, Bohra, and Dalal, in Press; Singh, Sidana, and Saluja, 1978). The models are causal, behavioural, and have capability to describe individual preferences as described in the next section.

Information Integration Theory

The primary goal of information integration theory is to develop simple models to describe how information is combined or integrated in judgement and decisions. The theory was originally developed by Norman H. Anderson (1970, 1974).

The theory assumes that each piece of information can be characterized by two parameters: a scale value, corresponding to the subjective evaluation of the information along the dimension of judgement, and a weight, representing the importance of the information for the judgement to be made. The integrated judgement or decision is assumed to be an algebraic function of the weight and scale values.

Factorial designs are typically employed where each subject receives all possible combinations of the levels of each factor, and is asked to respond to each of the hypothetical situations so formed. Responses are then analyzed to determine the relationships between informational variables and subjective judgements or decisions.

Most of the models fall in one of two main classes. One class includes adding, subtracting,and averaging models; other class includes multiplying and dividing models.

Averaging Models

Consider a set of N stimuli, S_i with value s_i and weight w_i. The averaging model specifies the response as a weighted average of the scale values. The overall judgement for attractiveness of bus systems, A_B, is assumed to be a weighted average of all the external information factors and an internal subjective opinion. Mathematically,

$$A_B = C + \left(\sum_{i=0}^{n} s_i w_i / \sum_{i=0}^{n} w_i \right) + \varepsilon \qquad (2)$$

where C is an additive constant which refers to an arbitrary zero on the response scale, and ε an additive random variable with zero mean. The internal variable refers to the past experience as having a scale value of s_0 and weight w_0. The s_i is the scale value of i^{th} attribute, and w_i the weight attached to i^{th} attribute. The test of the averaging model is straightforward . Depending upon the pattern of weighting of the two stimuli, the factorial plot of the row x column data will show parallelism or nonparallelism.

Parallelism Prediction

The parallelism prediction of the averaging model rests upon two important assumptions. First, the row and column stimuli do not interact or change their scale value at all when combined. Second, the row weight remains constant over rows, as does column weight across columns.

To show parallelism , it is necessary to plot the cell means. No a priori knowledge of scale value or weight is needed. Because of response variability, statistical test of parallelism is essential. If the data basically obey parallelism, then the row x column interaction term in analysis of variance would be zero in principle, and so nonsignificant in practice (Anderson, 1971).

Nonparallelism Prediction

When the assumption of equal weighting is not satisfied, parallelism cannot be expected to hold true. Statistical test of row x column effect would be significant. Nonparallelism can be of diverging or converging type. If the weight of the row factor is positively related with the scale value of the column factor, then the plot of the row factor data across the subjective functional values of the column factor will show a set of diverging straight lines (Anderson and Butzin, 1974; Graesser and Anderson, 1974; Singh, 1978). On the contrary, an inverse relationship between the weight of row factor and scale value of the column factor will engender a family of converging straight line (Anderson, 1972; Oden and Anderson, 1971; Leon, Oden and Anderson, 1973).

With both types of nonparallelism, the overall test of row x column effect would be statistically significant

and the entire interaction would concentrate in just a Linear x Linear trend. Statistical test for bilinear components would, therefore, be significant.

Alternative Models

Though parallelism and nonparallelism are consistent with the implication of a constant-weight and a differential weight average rules, they are also subject to alternative interpretations.

For example, parallelism supports both the constant weight averaging rule and the alternative adding rule. Similarly, a differential-weight averaging and the alternative multiplying rule predict a diverging set of straight lines (Anderson and Butzin, 1974; Graesser and Anderson, 1974; Kun, Parsons, and Ruble, 1974; Singh, Gupta, and Dalal, in press).

Averaging Versus Adding

To discriminate averaging from adding rule, additional data are required. In addition to ratings of stimuli from the main design, the subjects are asked to judge stimuli, having only the column information (Lampel and Anderson, 1968; Oden and Anderson, 1971; Singh, Bohra, and Dalal, in press).

According to the adding rule, the single-cue curve should plot as a straight line in a family of parallel lines. In contrast, the averaging rule predicts that the

single-cue curve should cross over some row curves, particularly those which are based on near-neutral value of the row factor. This crossover prediction has a simple logic. Since the value of a highly polar information is greater than the average of a highly polar and a mildly polar information combined, the single-cue curve in relation to a row curve will be lower at the negative end and higher at the positive end.

Differential-Weight Averaging Versus Multiplying

The multiplying model inplies that the single-cue curve should plot as curves in a family of diverging straight lines, for the multiplier row value is absent. On the contrary, the averaging rule mentioned earlier implies that the single-cue curve should cross over atleast one row curve.

This theory has been used by Norman and Louviere (1974) for prediction of mode choice using three factors: Fare, frequency, and walking distance to the bus stop. They showed that the behaviour followed a multiplying model which was supported by formal goodness-of-fit tests.

The study made by Levin and Corry (1975) differs in several respects from Norman and Louviere. Emphasis was placed on defining homogeneous subgroup of decision makers through behavioural measures. The single most unique finding of Levin and Corry was that the stimulus value received

greatest weight when it was consistent with the individual's initial bias.

Nicolaidis and Krishnan (1977) tested this methodology for planning bus service in California, and found it to be conceptually and operationally simple yet powerful from a statistical point of view.

The following chapters discuss in detail the application of information integration approach to the travel choice behaviour. A hypothetical bus system with varying attributes was presented to study the underlying behaviour in choice. Two experiments were conducted in order to study the modal choice behaviour and these are highlighted in the following chapters.

CHAPTER 2

Experiment 1

The main purpose of Experiment 1 was to model the travel decision of bus users. Accordingly, subjects received information pertaining to fare, frequency of running, and comfort of hypothetical bus systems, and indicated how much they would like to travel in the so-designed buses. If information available about fare, frequency and comfort are integrated according to a multiplying rule, then liking for a bus system would obey the following model;

$$A_B = \text{Fare} \times \text{Frequency} \times \text{Comfort}, \qquad (3)$$

where A_B = Attractiveness of a bus system.

Test of this multiplying model is simple. If stimuli are constructed according to a factorial design and data are analyzed through analysis of variance test, then a a three-factor design will produce three sets of diverging straight lines. If the multiplying model is correct, then Fare x Frequency, Fare x Comfort, Frequency x Comfort, effects will all be statistically significant. Graphically, therefore, each two-way interaction will display linear fan shape. Statistically, linear fan shape is equivalent

to significant Linear x Linear trend and nonsignificant residual trend.

Norman and Louviere (1974) tested the applicability of multiplying model in the travel decision of American college students. Hypothetical bus systems were described with respect to fare, frequency, and proximity, and judged probability of riding the bus indeed supported the multiplying model.

Two limitations of the study cited above make the multiplying interpretation of their results questionable. First, they used college students as respondents, who may undoubtedly be good at making precise judgement but may not constitute a general population of bus users. Second, and technically more important, they did not use any distingusbing test between multiplying and differential weight averaging. If the weight of one factor changes as a function of its own scale value as well as of the scale values of another factor, then multiplying type results can also be obtained (Anderson ,1971; Dalal,1978; Singh,1978).

A test between multiplying rule and the differential weight averaging rule can be made by asking for judgements based on only one piece of information. The multiplying rule can only operate if the subject infers some value for the missing information. With the infered value for

missing information the single-cue curve will still form part of linear fan. But if the averaging model operates, then the well known crossover interaction will be observed (Anderson, 1974a; Lampel and Anderson, 1968; Singh, Gupta, and Dalal, in press). No such test was used by Norman and Louviere (1974) or Norman (1977).

The present study used actual bus riders as subjects, and they differed considerably with respect to their income. In fact, the subjects were from high and low income groups. This will allow greater generality of the results.

Method

Stimuli and Design

Three types of descriptions of hypothetical bus systems were prepared on index cards. One set of bus systems were described with respect to fare, frequency, and comfort. Each factor had 3 levels, and the 27 three-cue descriptions were product of a 3x3x3 design. The levels of fare were 50 Paise, Rupee 1, and Rupees 1.50; the three levels of frequency of running were 15 minutes, 30 minutes, and 60 minutes; the 3 levels of comfort were not at all comfortable, okay, and very comfortable. These twenty-seven stimuli constituted the main design.

There were three 3x3 designs also: Fare x Frequency, Fare x Comfort, and Frequency x Comfort. The levels of the

three factors were the same as in the 3-cue main design described above. These designs were included to check reliability of results across 2- and 3- characteristic bus systems.

There were also nine single-cue hypothetical buses, based on one of the three levels of each factor. In addition to these, 4 three-cue, 6 two-cue, and 6 single-cue filler bus systems were prepared to serve as end anchors (Appendix B). Twelve practice examples were also constructed of those 12 examples, 4 had 3-cues, 4 had 2-cues, and the remaining 4 had just one cue (Appendix C). The practice examples were intended to serve as end anchors, and to orient the subjects toward the use of the complete response scale (Anderson, 1974c).

Response Scale

The response scale was the 4 cm x 5 cm wooden scale, containing 31 holes. Each hole had 0.5cm diameter, and was spaced at a distance of 1 cm. The extreme left hole was lebelled low and the extreme right was lebelled high on the subject's side. These holes had digits one to thirty-one written on the experimenter's side. To indicate liking for a particular bus system, subject inserted a pointer in the appropriate hole. The numbers assigned to these holes were treated as rating score.

Subjects

An incidental sample of twenty-four males served as subjects. Twelve subjects were from low income group, that is , their monthly income was below Rupees 500 per month. The remaining twelve subjects were from high income group, that is, their monthly income was above Rupees 1000 per month. Each subject spent approximately two hours in giving response to the stimuli presented to him.

Procedure

Before the collection of data, instructions (Appendix A) were given to the subject and a summary of the task was presented verbally. After the instructions, the experimenter ensured that the subject understood the task well. Experimenter then gave 12 practice examples to the subject. The subject read the typed information on the card, formed an opinion of the so-described bus system, and then indicated how much he would like to travel in that bus. In case of some of the subjects of lower income group, the experimenter described the task as well as stimuli in Hindi.

After practice, the experimental stimuli along with the filler ones were presented twice in different shuffled orders. Information on each card was also presented in two different sequence in order to avoid order of presentation effect on judgement of every bus system. Data from both

replications of the design were analyzed. All quiries by the subjects were answered and they were thanked for their cooperation.

Results

Main Analysis

Data of the three-cue design were subjected to a 2 x 3 x 3 x 3 , Replication x Fare x Frequency x Comfort analysis of variance, with repeated measurements on all the four factors (Winer, 1971). The results are summarized in Table 1.

According to the multiplying rule, all the three 2-way and the 3-way interactions should be statistically significant. Table 1 shows that Fare x Comfort and Frequency x Comfort effects were statistically significant. Contrary to the expectation,Fare x Frequency and Fare x Frequency x Comfort were nonsignificant. A multiplying model, cannot, therefore be accepted on the basis of results from the analysis of variance.

Graphic Analysis

Mean liking to travel judgements are plotted in the 3 panels of the Figure 1 as a function of Frequency x Fare, Fare x Comfort and Comfort x Frequency. It appears that the graphic results are also in accord with the results obtained from the analysis of variance. The left panel which plots

TABLE 1

Results from 2 x 3 x 3 x 3, Replication x Fare x Frequency x Comfort analysis of variance . Three-cue design .

Source	SS	df	MS	F
Replication(A)	13.85	1	13.85	0.147
A x Subjects	2164.10	23	94.09	
Fare (B)	10917.49	2	5458.74	26.07*
B x Subjects	9629.86	46	209.34	
Frequency (C)	4156.29	2	2078.14	14.34*
C x Subjects	6666.29	46	144.91	
Comfort (D)	34572.93	2	17286.46	59.48*
D x Subjects	13368.97	46	290.62	
A x B	58.76	2	29.38	1.00
A x B x Sub.	1341.93	46	29.17	
A x C	60.75	2	30.37	1.85
A x C x Sub.	752.27	46	16.35	
A x D	7.30	2	3.65	0.20
A x D x Sub.	833.05	46	18.10	
B x C	130.06	4	32.51	1.47
B x C x Sub.	2024.11	92	22.00	
B x D	679.25	4	169.81	7.20*
B x D x Sub.	2166.90	92	23.55	
C x D	290,93	4	72.73	3.10*
C x D x Sub.	2154.00	92	23.41	
A x B x C	93.49	4	23.37	1.42
A x B x C x Sub.	1512.44	92	16.43	
A x B x D	67.03	4	16.75	1.31
A x B x D x Sub.	1168.89	92	12.70	
A x C x D	100.92	4	25.23	2.20
A x C x D x Sub.	1045.34	92	11.36	
B x C x D	142.54	8	17.81	1.18
B x C x D x Sub.	2759.97	184	14.99	
A x B x C x D	55.99	8	6.99	0.62
A x B x C x D x Subjects	2065.64	184	11.22	

* $p < .05$

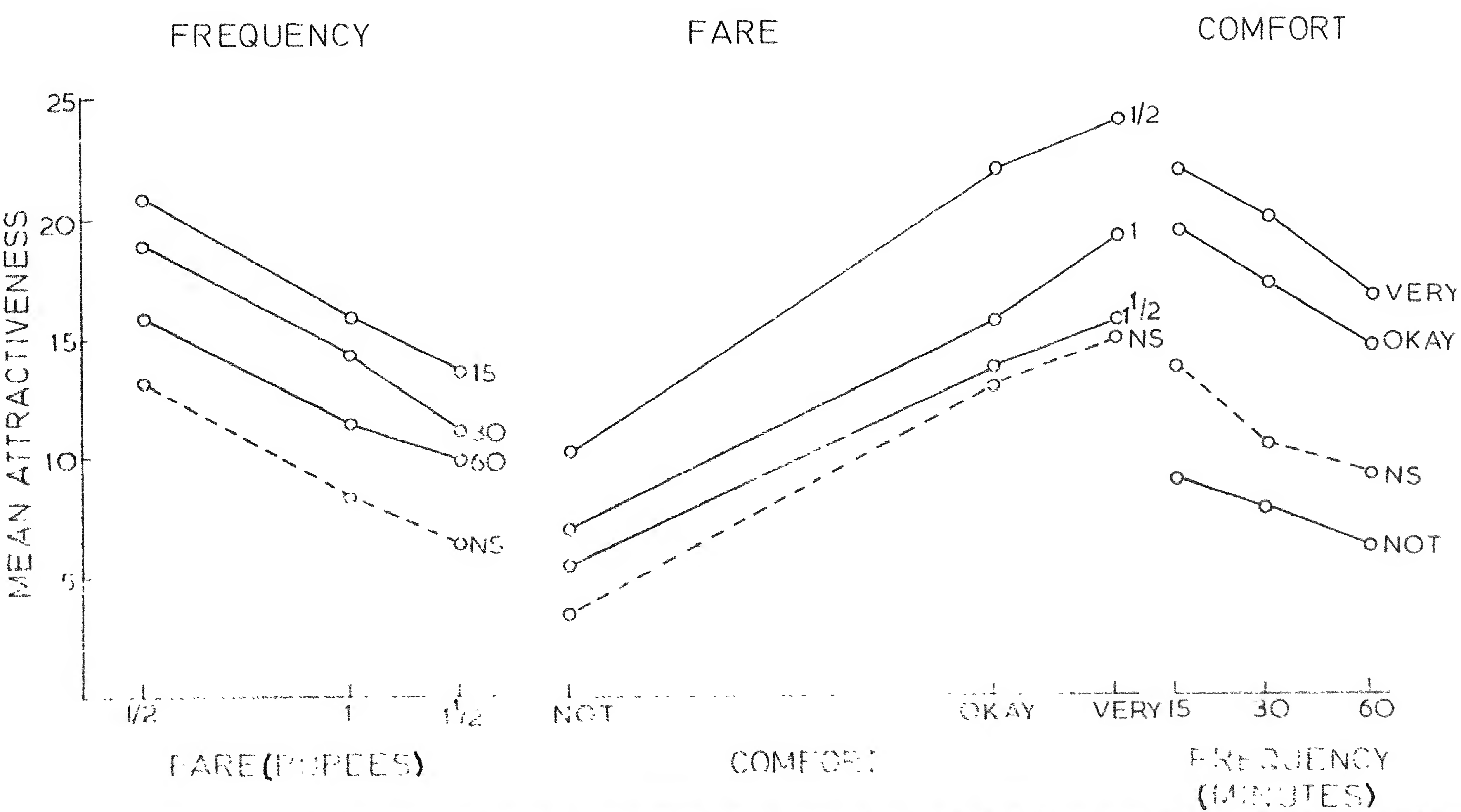

Figure 1: **Mean attractiveness of bus systems as a function of Frequency x Fare, Fare x Comfort, and Comfort x Frequency. The three panels are from main three-way design (data from Experiment 1). The NS curve is based on only the factor listed on the horizontal axis.**

mean liking as a function of frequency and fare shows clear parallelism. Parallelism pattern implies operation of an adding-type rule. The other two sets of curves have obvious divergence as was predicted from the multiplicative process.

The dashed curve of each panel which is based on the single information listed on the horizontal axis helps to diagnose the real model underlying the judgement. In the left panel, the dashed curve is at the bottom and it stand parallel to other three solid curves. This suggests that information pertaining to fare and frequency information are added together (Gupta, 1968) in judging attractiveness of bus systems. In the other two panels, on the other hand, the dashed curve form part of the linear fan shape. They do not show any tendency to crossover any of the three solid curves. That means that comfort information multiplies both fare and frequency information.

As the results stand, the multiplying model demonstrated by Norman and Louviere (1974) and Norman (1977) is only partially supported. Perhaps compcund adding-multiplying model could better be able to account for the results. Accordingly, it can be said that

$$A_B = (\text{Fare} + \text{Frequency}) \times \text{Comfort} . \qquad (4)$$

Economic Condition

As equal number of subjects were from high and low income groups, economic condition was added as a classification factor in the main four-way analysis of variance. In this five-way analysis, Income x Comfort effect was statistically significant , $\underline{F}$ (2,44) = 3.32, $\underline{P} < .05$. Table 2 presents mean liking to travel as a function of economic condition of the subjects and the comfort of the bus system.

Table 2 shows that attractiveness judgements based on comfort factor were more extreme in case of high than low income group. That is, the difference in the attractiveness of not at all comfortable and very comfortable bus system was greater for high rather than low income group. Similar results emerged in a two-cue, Frequency x Comfort, design also.

On purely common sense basis, economic factor can be expected to moderate effectiveness of fare information. The present results, however, denote that economic condition of subject moderates effectiveness of comfort factor.

Two-cue Design

Table 3 presents results for three separate 2 x 3 x 3 analyses of variance- - Fare x Frequency, Fare x Comfort and Frequency x Comfort.

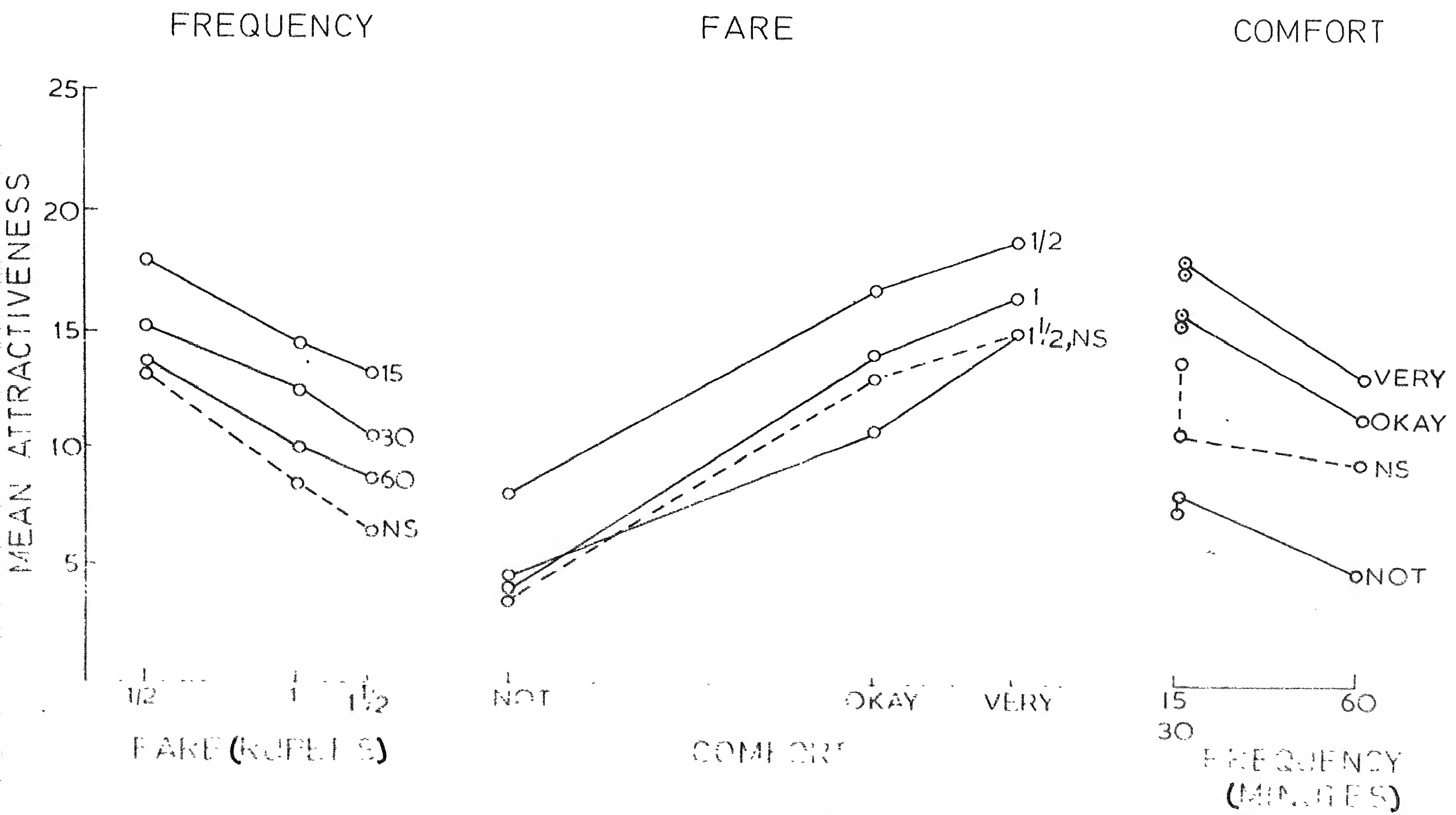

Figure 2: Mean attrictiveness of bus system as a function of Frequency x Fare, Fare x Comfort, and Comfort x Frequency. (Data from Experiment 1). The NS curve is based on only the factor listed on the horizontal axis.

TABLE 2

Mean liking to travel as a function of economic condition and comfort.

Economic Condition	Comfort		
	Not at all	Okay	Very
Low	8.56	15.60	18.04
High	6.86	18.73	21.39

TABLE 3

Results from 2 x 3 x 3 analysis of variance. Two-cue designs.

Fare x Frequency			Fare x Comfort			Frequency x Comfort		
Source	df	F	Source	df	F	Source	df	F
Replication(A)	1	2.27	Replication(A)	1	6.72	Replication(A)	1	0.04
Fare (B)	2	10.33	Fare (B)	2	8.83	Frequency (C)	2	11.23
Frequency (C)	2	16.62	Comfort (D)	2	56.25	Comfort (D)	2	34.10
A x B	2	2.15	A x B	2	0.51	A x C	2	0.09
A x C	2	3.92	A x D	2	4.56	A x D	2	0.42
B x C	4	0.11	B x D	4	2.00	C x D	4	1.24
A x B x C	4	0.74	A x B x D	4	0.99	A x C x D	4	0.40

It is clear from Table 3 that when the three factors were presented in a pair-wise manner, the subjects adopted a simple additive rule. As two-way interaction is non-significant in all the three analyses it can safely be said that the judgements based on two-cues obey additive model.

Qualitative Results

It can be observed from Figure 1 that the different levels of each factor are spaced on the horizontal axis according to their functional values (Anderson, 1976, 1977). Such a spacing allows rescaling of the physical values of the stimuli, and the results of the present study throw some light on this virtue of functional measurement.

In the left panel, the three columns are spaced in terms of the psychological values of fare. According to their physical value, 50 Paise, Re. 1, and Rs.1.50 are equidistant. Psychologically, however, they are not so. The psychological difference between 50 Paise and Re. 1 is much larger than that between Re.1 and Rs. 1.50. Similarly, the psychological values of service frequency of 15 minutes, 30 minutes, and 60 minutes do not match with the physical value of time. The difference between half an hour and one hour is psychologically not much different from the difference between 15 minutes and 30 minutes.

This result is interesting, for it shows that planners and decision makers involved in engineering sciences just can not go by the physical values of the stimuli. It is by no means less important to know the subjective reactions to the stimuli, and information integration approach is ideally suited to study the perception of transportation systems.

Discussion

Findings of Experiment 1 are mixed. The results of the three-cue design suggest that attractiveness of bus system follows a compound adding-multiplying model, that is, Equation 4. Accordingly, it can be expected that a similar relationship will hold with two-cue stimuli. Unfortunately, however, the results from the two-cue design do not match. The two-cue results suggest the operation of an additive model, where as the results from three-cue design suggest adding-multiplying model.

In addition to this difference between the results of three-and two-cue designs, results from the three-cue design do not agree with the findings reported with the American subjects (Norman and Louviere, 1974; Norman, 1977). This may be because of the difference in the nature of the cultural difference between two types of subjects (Singh, Gupta, and Dalal, in Press).

Before the results of Experiment 1 are accepted as supportive of a compound adding-multiplying model, replication of the results seems to be necessary. Therefore, Experiment 2 was conducted with another sample which permitted check on the consistency of the results obtained in Experiment 1. The following chapter discusses some of the main conclusions derived in the replication of Experiment 1.

CHAPTER 3

Experiment 2

The main purpose of Experiment 2 was to check the reliability of the results of Experiment 1. A new group of twenty-four subjects, 12 from low income group and 12 from high income group were selected, and they were given the same experimental task. The only difference between Experiments 1 and 2 was that each subject rated the experimental stimuli 3 times and data from all the three replications were analyzed.

Results

Main Analysis

Table 4 lists results from a 3 x 3 x 3 x 3, Replication x Fare x Frequency x Comfort analysis of variance. As in Experiment 1, the three main effects for fare, frequency, and comfort are highly significant. The two-way and the three-way interaction involving the factors of fare, frequency, and comfort are also as predicted. Fare x Frequency and Fare x Comfort effects are statistically significant. But Frequency x Comfort, F (4,92) = 2.46, $p < 0.06$ and Fare x Frequency x Comfort F (8,184) = 1.70 , $p < .06$ are marginally significant. The present results are thus in accord with the multiplying model proposed by Norman and Louviere (1974).

TABLE 4

Results from 3 x 3 x 3 x 3, Replication x Fare x Frequency x Comfort Analysis of variance Three-cue design.

Source	SS	df	MS	F
Replication (A)	33.53	2	16.76	0.298
A x Subjects	2586.81	46	56.23	
Fare (B)	11028.27	2	5514.13	10.576*
B x Subjects	23983.91	46	521.38	
Frequency (C)	4563.93	2	2281.96	19.32*
C x Subjects	5432.78	46	118.10	
Comfort (D)	30752.53	2	15376.26	50.47*
D x Subjects	14013.06	46	304.63	
A x B	36.18	4	9.04	0.337
A x B x Subjects	2461.21	92	26.75	
A x C	2.39	4	0.59	0.039
A x C x Subjects	1360.27	92	14.78	
A x D	344.31	4	86.07	6.125*
A x D x Subjects	1293.00	92	14.05	
B x C	298.09	4	74.52	2.60*
B x C x Subjects	2636.94	92	28.66	
B x D	654.08	4	163.52	4.92*
B x D x Subjects	3052.71	92	33.18	
C x D	287.71	4	71.92	2.46**
C x D x Subjects	2683.23	92	29.16	
A x B x C	129.42	8	16.17	1.19
A x B x C x Sub.	2491.38	184	13.54	
A x B x D	135.73	8	16.96	1.56
A x B x D x Sub.	1992.36	184	10.82	
A x C x D	80.18	8	10.02	0.88
A x C x D x Sub.	2094.02	184	11.38	
B x C x D	387.44	8	48.43	1.70***
B x C x D x Sub.	5215.67	184	28.34	
A x B x C x D	273.34	16	17.39	1.33
A x B x C x D x Sub.	4776.79	368	12.98	

* $p < 0.5$, ** $p < 0.06$

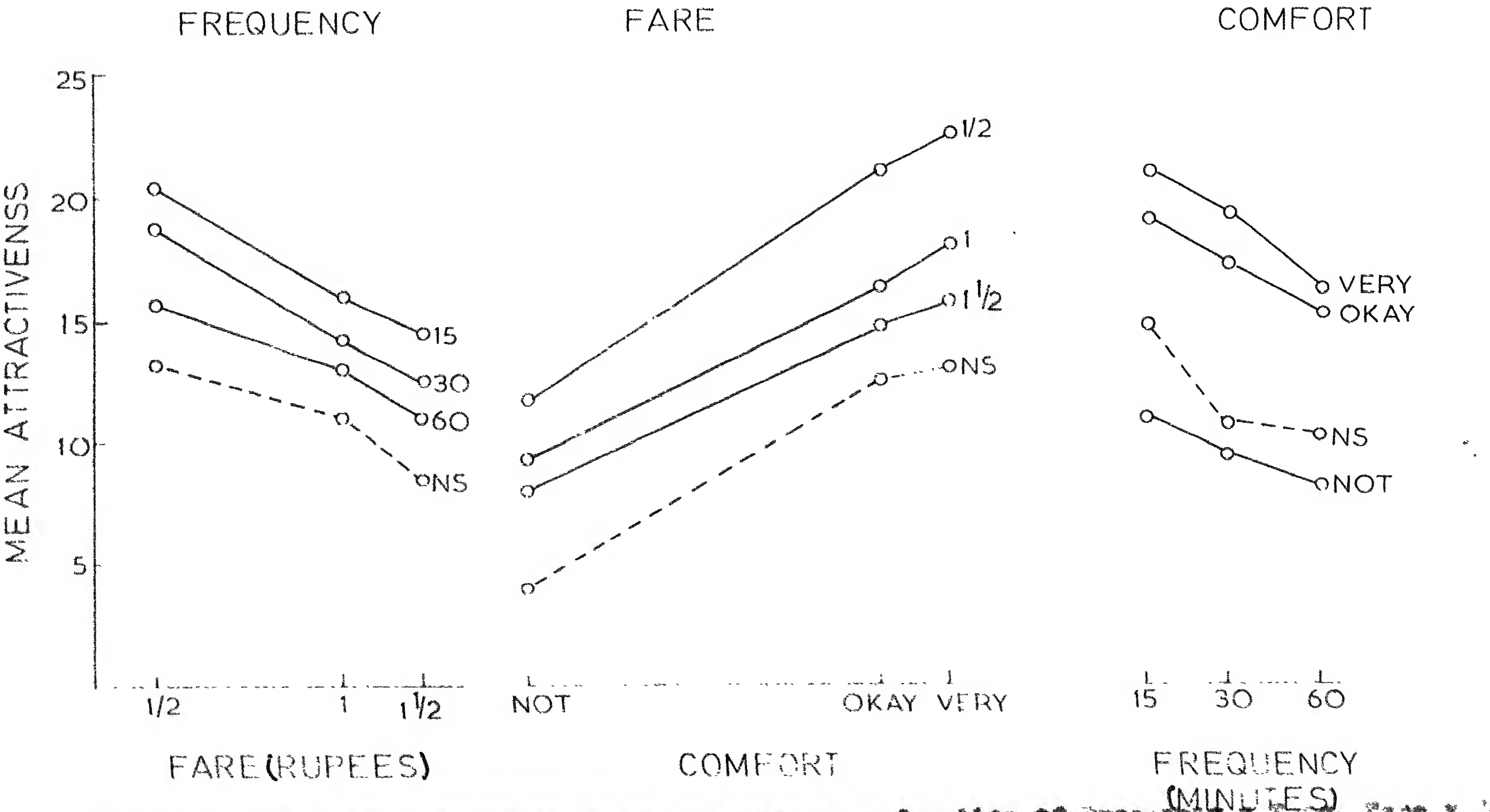

Figure 2: Mean attractiveness of bus systems as a function of frequency x fare, fare x comfort, and comfort x frequency. The three panels are from main three-way design (data from Experiment 2). The NS curve is based on only the factor listed on the horizontal axis.

Graphic Analysis

To appreciate the operation of the multiplying model, look at the three panels of Figure 3. All three panels show clear divergence toward the right. This visual inspection is further supported by trend analysis, which disclosed that the entire interaction effect concentrated in only the Linear x Linear trend. For Fare x Frequency, Fare x Comfort,and Frequency x Comfort effects, the Linear x Linear trend had statistically significant F ratios of 4.76, 18.20 and 8.18 with degree of freedom of 1/92. The F for residual of the three effects were 1.87, 0.50, and 0.55 , with degree of freedom of 3/92, respectively, and they did not reach the acceptable level of significance. These results suggest that the dominant property of the curves of the three panels may indeed be characterized by a linear fan shape.

Further support for the multiplying model comes from the dashed curves of each panel. As implied by the multiplying rule, the dashed curve of each panel forms part of linear fan shape. As in Experiment 1 the dashed curve based on frequency information only is above the solid line for not at all comfortable bus system. This indicates that subjects assume that each bus is comfortable to some extent.

Inclusion of the factor of the economic condition of subjects in the main design did not disclose any meaningful result. Results pertaining to economic condition and comfort of Experiment 1 thus does not appear to be replicable.

Two-cue Results

Table 5 presents results from three separate 3 x 3 x 3 analyses of variance for the two-cue, Fare x Frequency, Fare x Comfort, and Frequency x Comfort sub-designs.

As in Experiment 1, information about two pieces of information seems to be coordinated by an adding-type rule. As interaction between the two factors is nonsignificant in each of the three analyses, it can safely be said that profile of each two-way interaction is characterized by parallelism.

Qualitative Results

The functional values of the three informational factors appear to be similar to those reported in Experiment 1. The difference between 50 Paise and Re. 1 is again much larger than the difference between Re. 1 and Rs. 1.50. Psychological values of time observed in Experiment 1 are also comparable with those of Experiment 2. Psychologically, the difference between 15 minutes and 30 minutes is not much different.

TABLE 5

Results from 3 x 3 x 3 analysis of **variance** Two-cue designs.

Fare x Frequency			Fare x Comfort			Frequency x Comfort		
Source	df	F	Source	df	F	Source	df	F
Replication(A)	2	0.32	Replication(A)	2	0.41	Replication(A)	2	1.33
Fare (B)	2	6.65	Fare (B)	2	8.59	Frequency (C)	2	15.41
Frequency (C)	2	9.97	Comfort (D)	2	45.16	Comfort (D)	2	28.95
A x B	4	1.15	A x B	4	0.79	A x C	4	0.26
A x C	4	2.42	A x D	4	1.93	A x D	4	2.47
B x C	4	0.32	B x D	4	2.16	C x D	4	1.44
A x B x C	8	0.67	A x B x D	8	0.97	A x C x D	8	0.83

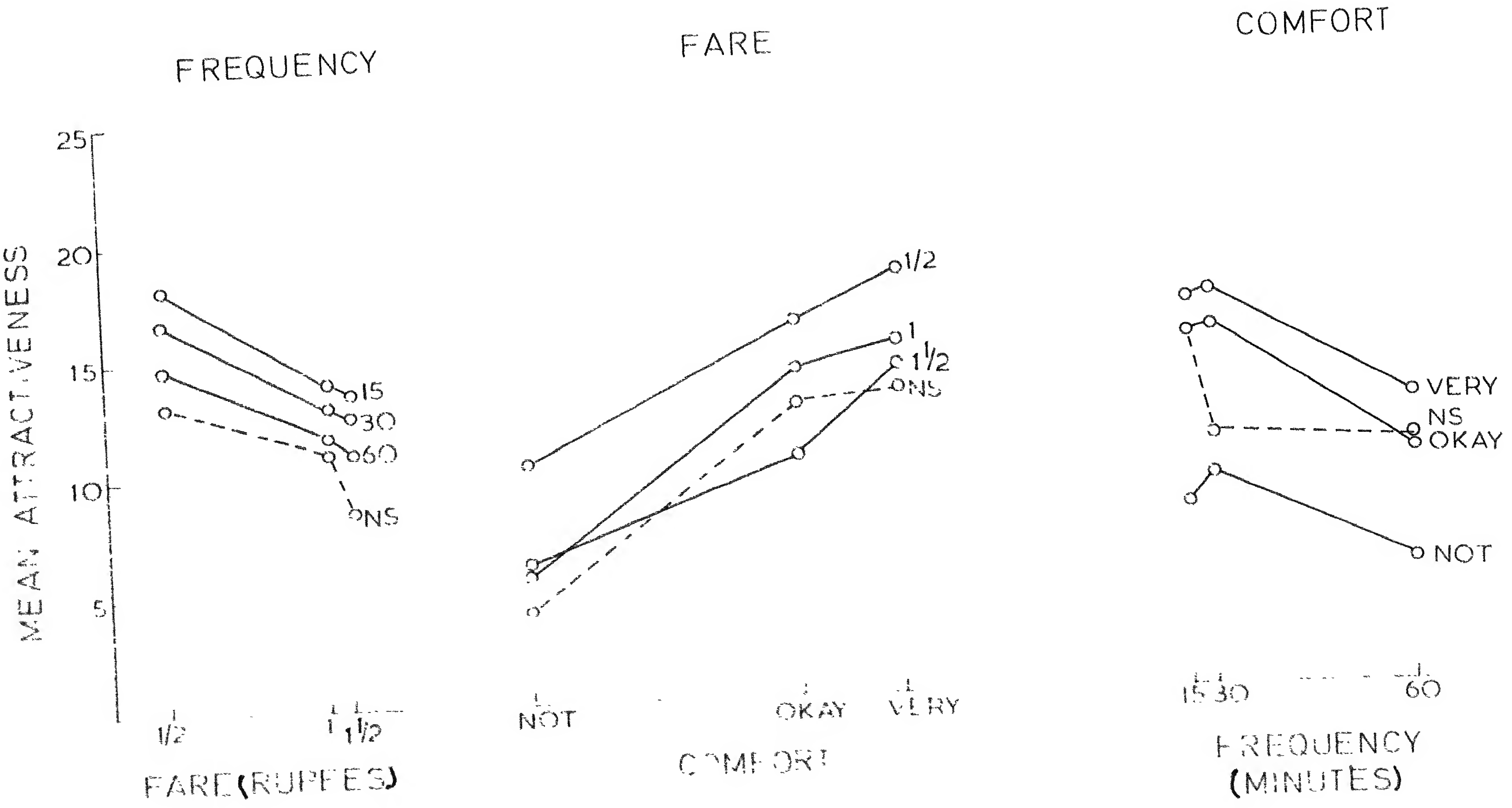

Figure 4: Mean attrictiveness of bus system as a function of Frequency x Fare, Fare x Comfort, and Comfort x Frequency. (Data from Experiment 2). The NS curve is based on only and factor listed on the horizontal axis.

According to functional measurement, the marginal row and column means constitute validated interval scale values of the row and column stimuli (Anderson, 1966, 1977). To show the utility of these functional values, response to each cell mean was predicted from the multiplying model. Accordingly, the functional value of a particular cell was treated as equal to the product of row and column means divided by the grand mean (Dalal,1978 , p. 41) . The mean absolute deviations between predicted and observed responses were 0.26 , 0.13 and 0.12 for Fare x Frequency, Fare x Comfort, and Frequency x Comfort, respectively. These deviations seem to be negligible along the 31-point scale. It can thus be said that multiplying model could give a reasonably good account for the three-cue data of Experiment 2.

Discussion

Results of Experiment 2 are important in two ways. First, they conclusively show that attractiveness of bus systems obeys a multiplying model. The failure to obtain support for the multiplying model in Experiment 1 was thus perhaps because of lower sensitivity of the Experiment 1. It should be noted here that Experiment 1 required the subjects to rate stimuli only twice, where as Experiment 2 required the subjects to rate stimuli thrice. A sensitive

design is therefore more useful in diagnosing the multiplying process than nonsensitive one.

Evidence for the multiplicative process may not be considered as novel finding, for Norman and Louviere (1974) and Norman (1977) supported a similar rule. What is more important here is that the present method, particularly the use of a distingushing test between multiplying and differential weight averaging, puts the multiplying results on a more solid ground. It also deserves mention that the present results extends the multiplying process to a general population of bus users.

The second important finding is that the attractiveness of bus system based on two characteristics follow simple adding type rule. This result is identical to that of Experiment 1. As this result is reliable and replicable, it seems appropriate to suggest that multiplying type strategy is employed in rating of only complex bus systems. Incidently, psychologists interested in testing and developing integration model have not paid much attention to this aspect. The present results call their attention to the problem of changes in integration rule as a function of task complexity.

Findings of Experiments 1 and 2 also suggest the utility of functional measurement of the subjective values of stimuli. Undoubtadly, people vary in their value for

different stimuli and to make any new system acceptable to them, we must know how they feel about the characteristics of the system. Results related to perception of time and money bear directly on the utility of this approach, and suggest that the study of multiple determinants of transportation choice can be simplified considerably through the methods of information integration theory.

The following chapter presents the salient conclusions derived from the study. In addition, suggestion for further research in this area have been suggested.

CHAPTER 4

Conclusion

The previous chapters highlighted the utility of information integration theory in the analysis of modal choice decision-making process. The application of this theory was made to the choice of hypothetical bus systems with varying attributes, using residents of I.I.T. Kanpur as subjects.

The two experiments described earlier show that human judgement in transportation can be studied in laboratory using information integration approach. The experiments proved useful in determining the influence of fare, frequency, and comfort, and showed how these factors are evaluated and combined to determine modal-choice behaviour.

Although the two experiments do not show the same results, they throw enough light on understanding the travel behaviour. In Experiment 1, a compound adding-multiplying model was supported when three pieces of information were given. When two pieces of information were given, a simple additive model was able to account for the results. It shows that when the task is simple, subjects add their responses. On the otherhand, when the task is complex,

nonadditive type model holds true. This result is also supported in Experiment 2. In three-cue task, however, a multiplying model was supported. This shows that travel decision obeys multiplying rule.

One important finding of the present research is that it challenges the conventional view that physical characteristics of bus system have the absolute values , a notion which has called for the use of regression analysis in transportation research as mentioned earlier.

The psychological difference between 50 Paise and Re. 1 is much larger than the difference between Re. 1 and Rs. 1.50 . Even the psychological scale of frequency of service did not quite conform with the objective scale of frequency of service. That calls attention to the fact that good prediction about travel decision has to consider psychological values of transportation systems. Methodologically, this implies that often used regression analysis is not as good as it has been believed to be (Shanteau and Anderson, 1977).

Suggestions for Further Research

For further work on transportation decision making, the following points need to be considered:

1. In the present study, only three factors were taken for determining the attractiveness of bus systems. For

better understanding of the modal choice judgement, several other factors should also be included in the study such as travel time, safety, purpose of trip, etc.

2. Subjects should be given sufficient practice to make them familiar with the task before responses are collected for analysis. As it has been suggested prior practice results in more meaningful data. especially for modal analysis.

3. It should be emphasized that the present results are based on a smaller sample of subjects. To generalize the results, subjects from various strata of the population, covering a broad spectrum of socioeconomic characteristics, should be studied.

4. The task could be extended to included other modes and other transportation-related problems. This will provide more generality to the results. For example, urban researchers are interested in the joint choice of residence location and transportation mode. The information integration approach could be applied by simultaneously varying factors such as distance to work, distance to shopping centers, and availability of transportation modes.

5. More research is needed to validate the information processing models derived in laboratory studies by applying them to actual transportation decisions.

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APPENDIX A

An agency is interested in introducing a new bus system for the campus community. The agency wants to know how do bus users consider different characteristics of a system. In this experiment, therefore, you will have to judge your preference value for a system with given attributes.

I will give you information about Fare, Frequency of service, and comfort of several bus systems, and you have to indicate how much you would like to take a bus with the characteristics given. The fare will range from Paise 35 to Rupees 2/-, frequency of service will range from every 5 minutes to every hour, comfort that you can have will vary from extremely uncomfortable (overcrowded, standing, poor seating facilities etc.) to extremely comfortable (excellent seating facilities, no standing allowed etc.).

These three pieces of information will be presented to you on cards in different combinations. Every time you receive a card, read the typed information carefully, think how much you would like to ride in a bus having the supplied characteristics. Your liking for the system will be indicated along this 31 holes scale. The first hole in the left side means that you would not like to travel in the described bus.

As you move from left to right, your liking for the bus is increasing. You have to indicate your liking every time by showing the appropriate hole of the scale.

All buses would not be described by all the three characteristics In some cases, information about one of the three characteristics would be missing; in other cases, information pertaining to two characteristics would be missing. In every case, you try to judge its likableness on the basis of only the supplied information. Also, try to use the entire response scale in indicating your preference.

In order to make you familiar with the nature of the task and the use of the response measure, I will give you some practice examples. You try to understand the task clearly. Feel free to ask any question you may have.

After the practice session, we will begin the actual work. I will present 78 cards to you and one by one. You will read the information contained in the card, and indicate how much you would like to travel in that bus. You will be rating each card two times in different, random orders. Please take the task seriously, and extend your genunine cooperation.

Thanking you.

APPENDIX B

Practice examples used in Experiment 1 and 2 are listed below.

PRACTICE 1	Fare	=	Paise 35 only
	Frequency	=	Every 5 minutes
	Comfort	=	Extremely comfortable
PRACTICE 2	Fare	=	Paise 35 only
	Frequency	=	Every hour
	Comfort	=	Extremely comfortable
PRACTICE 3	Fare	=	Rupees 2 only
	Frequency	=	Every hour
	Comfort	=	Extremely uncomfortable
PRACTICE 4	Fare	=	Rupees 2 only
	Frequency	=	Every 5 minutes
	Comfort	=	Okay
PRACTICE 5	Fare	=	Paise 35 only
	Frequency	=	Every 5 minutes
PRACTICE 6	Fare	=	Paise 35 only
	Comfort	=	Extremely confortable
PRACTICE 7	Fare	=	Rupees 2 only
	Comfort	=	Extremely uncomfortable
PRACTICE 8	Frequency	=	Every hour
	Comfort	=	Extremely uncomfortable

PRACTICE 9	Fare	=	Paise 35 only
PRACTICE 10	Fare	=	Rupees 2 only
PRACTICE 11	Frequency	=	Every 5 minutes
PRACTICE 12	Comfort	=	Extremely uncomfortable

APPENDIX C

End auchors used in Experiments 1 and 2 are listed below.

CARD 0	Fare	=	Paise 35 only
	Frequency	=	Every 5 minutes
	Comfort	=	Extremely comfortable
CARD 28	Fare	=	Paise 35 only
	Frequency	=	Every hour
	Comfort	=	Extremely comfortable
CARD 29	Fare	=	Rupees 2 only
	Frequency	=	Every hour
	Comfort	=	Extremely uncomfortable
CARD 30	Fare	=	Rupees 2 only
	Frequency	=	Every 5 minutes
	Comfort	=	Okay
CARD 58	Fare	=	Paise 35 only
	Frequency	=	Every 5 minutes
CARD 59	Fare	=	Rupees 2 only
	Frequency	=	Every hour
CARD 60	Fare	=	Paise 35 only
	Comfort	=	Extremely comfortable

CARD	61	Fare	=	Rupees 2 only
		Comfort	=	Extremely Uncomfortable
CARD	62	Frequency	=	Every 5 minutes
		Comfort	=	Extremely comfortable
CARD	63	Frequency	=	Every hour
		Comfort	=	Extremely uncomfortable
CARD	73	Fare	=	Paise 35 only
CARD	74	Fare	=	Rupees 2 only
CARD	75	Frequency	=	Every 5 minutes
CARD	76	Comfort	=	Extremely uncomfortable
CARD	77	Comfort	=	Extremely comfortable
CARD	78	Frequency	=	Every one hour